NASA Robotics Internship Program Student Guide

June 6 – August 12, 2005

Objectives :

The motivation for this initiative stems from the enhanced role robotics is expected to play in NASA's space exploration vision and the unique opportunity it offers to generate enthusiasm for science, technology, engineering and mathematics. The goal of this internship is to provide an avenue for students to participate in challenging and inspiring projects at the frontiers of robotics research being conducted at NASA, academic institutions and industry.

Eligibility Criteria :

Interns: The interns should be rising freshmen or sophomores in college. Interns will be selected based on excellence in academic performance (minimum GPA 3.0); demonstrated prior involvement in robotics and propensity for teamwork. To apply, applicants should

- Provide two letters of recommendation from persons that can specifically address their strengths in the selection criteria listed above.

- Carefully read the **Project Descriptions** section below. Applicants should then select their three most preferred team projects and explain why they are especially well suited for those projects in a brief essay.

- Complete the on-line application for the **NASA Robotics Internship Program** at http://university.gsfc.nasa.gov/application/ **before January 31, 2005**.

Team Leads: The team leads should be advanced undergraduate or graduate students with a curricular focus in robotics. Team leads will be selected based on academic excellence, past research experience, leadership skills and interest in serving as a mentor for less advanced undergraduate students. **Please note that the team leads will be recruited through the following GSFC internship programs: NASA Academy Goddard, SIP, SAWDRIP, or APL**. To apply for the team lead position, applicants should

- Provide two letters of recommendation from faculty or past/current employers who can speak to their strengths in the areas listed above.

- Carefully read the **Project Descriptions** section below. Applicants should then select three most preferred team projects and explain why they are especially well suited to serve as team leads for those projects in a brief essay.

- Complete the on-line application for the **NSAS Academy Goddard, SIP, SAWDRIP or APL** internship programs available at http://university.gsfc.nasa.gov/application/ **before January 31, 2005**.

Basic Format:

- A 10-week, resident summer internship.
- Interns will work on projects in teams consisting of one team lead and 2-3 students each. Each team will be assigned to a single project.
- The project Principal Investigators (PI's) will set the direction and oversee the week-to-week progress. To minimize drain on PI time, the team leads will guide students and manage the project on a daily basis as their independent research assignment.
- In addition to team projects (80%), the interns will participate in a joint core group project (5%) as well as enriching activities such as lectures, meetings with leaders in the field (10%) and travel to NASA centers and other institutions active in cutting edge robotics development (5%).

Weekly Layout:

Week	**Monday**	**Tues**	**Wed**	**Thurs**	**Thurs Evening**	**Friday**
1. Initiation	Orientation	Initiate Team Projects			Dinner w/ Friday Speakers/ Leaders in the Field.	Lectures* & Group Project
Typical Week	Team Projects				Dinner w/ Speakers/ Leave for Field Trip	Lecture & Group Project/ Field Trip**
5. Mid-term Report	Team Projects					Midterm Presentations
10. Graduation	Wrapping up Team Projects					Presentations, Keynote Speech, Awards, Luncheon with Parents & PI's.

* Lectures: These will be on topics such as the role of robotics at NASA and other cutting edge topics in robotics.

** Field Trips: Overnight trip to Johnson Space Flight Center or the Jet Propulsion Laboratory, and MIT Artificial Intelligence Lab; day trip to Carnegie Mellon University;
a visit with the RoboCup interns at Johns Hopkins University, visits to all labs hosting team projects. The day trips will be scheduled for Friday. For overnight trips departure will be arranged for Thursday evening.

Financial Support, Housing and Travel:

Interns: Interns will receive a $5K stipend. Interns will be housed in a single fraternity house at the University of Maryland, College Park. The cost of housing (estimated to be around $1300 for the 10 week period), most meals, and travel to and from Maryland will be the responsibility of the interns. Thursday evening dinners and travel expenses for field trips will be covered by GSFC.

Team Leads: Team leads will be housed in a fraternity house at the University of Maryland along with other participants of the internship program (i.e., NASA Academy, SIP, SAWDRIP, or APL) through which they are recruited. Terms for stipends and responsibility for cost of travel to and from Maryland vary with the internship. Applicants should refer to the individual program for details. Travel expenses for field trips will be covered by GSFC.

2005 NASA Robotics Internship Program Team Projects

#	Keyword	PI's	Organization	Project Title
1	VOIR	Dr. Bill Heaps, Dr. Kevin Moore, Ms. Ann Darrin	GSFC& JHUAPL	Visual Obstacle Identification Robotics
2	ASFT	Barbie Medina	GSFC	Adaptive Sensor Fleet (ASF)-Terrestrial
3	HIRC	Dr. Corinna Lathan	Anthrotronix, Inc.	Development of Advanced Human-Robot Interfaces for CosmoBot, An Interactive Robot for Children
4	RRPA	Dr. David Akin	UMCP	Development of Robotic Rover Prototypes to Assist Astronauts with Surface Exploration Tasks
5	VFRS	John Vranish, Julia Loftis, Rud Moe	GSFC	"Virtual Feel" Robotic Servicing
6	CVAT	Jacqueline Le Moigne, Michael L. Rilee, John E. Dorband	GSFC	Computer Vision for the ANTS TetWalker
7	MTRS	Dr. Steven A. Curtis Dr. Michael Desch/ Dr. Walt Truszkowski	GSFC	Modelling of Tetrahedral-based Robotics Structures.

PROJECT DESCRIPTIONS:

Project Title: Visual Obstacle Identification Robotics (VOIR)

PI's: Dr. William Heaps (GSFC) and Dr. Kevin L. Moore (JHUAPL)
Project Coordinator: Ann Garrison

Student Aide:
Kara Berke (410-740-9943)

The Johns Hopkins University Applied Physics Lab (JHUAPL)is pleased to propose a targeted plan for the NASA Robotics Internship Program. This program VOIR, Visual Obstacle Identification Robotics, would supplement the 3D robotic laser vision project. The JHAUPL has in place a formal agreement to team with NASA Goddard Space Flight Center on an investigation of 3D robotic laser vision. This activity is formally being sponsored by NASA HQ Code T Office of Exploration. The PI at NASA Goddard is Dr. William Heaps (301-286-5106). This formal program will begin in early CY 2005. This is an ideal program to be supplemented under the NASA robotics internship program with a team of interns to supplement the primary investigation activities. These students would primarily be situated at the JHUAPL facility in Laurel MD where they would be under the lead of Dr. Kevin Moore, a leading expert in autonomous controls and robotics. In addition, Ms. Ann Garrison Darrin of JHUAPL would act as program coordinator. The use of a funded substantial program as the base for the student activities will assure that the interns are exposed to a broad range of space robotics activities. In addition, the 3D robotic laser vision will benefit by the ability to expand their investigations through the use of this team to robotic navigation in obstacle riddled situations.

Laser 3D Vision is an enabling technology directly recommended by the Report of the President's Commission on Implementation of the United States Space Exploration Policy (ISBN 0-16-073075-9). It has been proposed that this technology would be useful for extended operations on the lunar surface by robots or humans, particularly during prolonged periods of profound darkness.

This same technology could also effectively help to guide an unmanned vehicle around a series of obstacles. 3D laser imaging presents a feasible, low-cost range tracking system which could accomplish this task. The 3D imaging system would be better implemented on a vehicle limited to the scope of Earth's atmosphere as problems arise in creating a system that could operate in space, both in developing and testing such a system. Applying the technology to an Earth-restricted vehicle, would be a much more approachable and cost-effective task.

The problem of navigating an unmanned vehicle can be addressed by analyzing the distance or range of an obstacle in the path of the vehicle. Human vision can range from a few inches to infinity with augmentation to extremely short distances, with intense detail, with the use of a microscope and extremely long distances, though with less clarity, by a telescope. In order to navigate an unmanned vehicle, it is only necessary for the range of the sensors on the vehicle to span from a few meters to several kilometers. This is where laser imaging technology could prove effective, as a relatively small laser could be used.

A team of three to four college freshmen and sophomores, led by an advanced undergraduate student or graduate student could adopt such a project, their goal: to incorporate 3D laser imaging system with an unmanned vehicle in order to guide the vehicle around a series of obstacles in its path of motion.

This could be accomplished using LIDAR technology to refract a laser beam into a collection of beams and collect data in an array of optic fibers from each of the refracted beams. The data, consisting of the time it took for each beam to return to the vehicle, would instruct the vehicle of the distance between it and any obstacles that may appear in its path.

The advanced undergraduate/graduate (Team Lead) will lead the other members of the team incorporating the LIDAR system with a vehicle. It would be necessary for such a leader to coordinate his/her team towards the intended goal through a combination of supervision, guidance, and collaboration with the team members.

Due to the nature of the onsite work at the JHUAPL, students should be US citizens and will need to be able to pass a clearance. It is expected that the same system used to place students in conjunction with programs sponsored by NASA Goddard would be used for this activity.

Student Team Lead Position Description: Technical knowledge of embedded systems design, real-time programming, wireless communication, signal processing, and control systems design required. Experience completing a project in a team environment desired.

Student Intern Position Description:
Interns will work to integrate a 3-D LIDAR system with an unmanned vehicle for navigation and motion control, including sensor signal processing, hardware development and interfacing, embedded system and real-time programming, obstacle avoidance algorithms and path tracking controller designs, wireless communication, and visualization software.

Project Title: Adaptive Sensor Fleet (ASF)- Terrestrial (ASFT)

PI: Barbie Medina, GSFC

One key element of NASA's exploration initiative is to conduct robotic exploration of Mars and across the solar system. Advances in robotic technology will play a key role in enabling this new vision. Current Martian robotic missions each involve a singular rover which is tightly constrained by a predetermined task schedule. However, to better explore different terrestrial environments, the concept of Distributed Autonomous Robotic Systems (DARS) must be researched, prototyped and introduced into future robotic missions.

There are multiple organizations, both within and outside of NASA, who are working on advancing the state of robotic hardware. The Advanced Architectures and Automation Branch, Code 588, has put together a small civil servant team to assist in the advancement of the state of the art in intelligent robotic control software. To accomplish this we are currently building the Multipurpose Exoterrain for Robotic Studies (MERS) in the Building 23's courtyard. We envision NASA, university, and industry partners using MERSto demonstrate advanced software control concepts for robotic missions. These concepts include:

- o Goal and event driven automation
- o Advanced automation through predictive modeling
- o Self organizing systems
- o Multi-agent collaborative systems
- o Optimal path planning and fleet management.
- o Learning systems
- o Data management (mining, fusion)

The first use of the MERS is to demonstrate basic multi-platform collaboration based upon high-level goal definition. This will be accomplished by adapting innovative concepts currently under development in GSFC Code 580 for a fleet of autonomous ocean vessels. The vessels are slated to demonstrate the exploration of ocean eddies in FY05. The technologies being applied are directly applicable to rovers studying rocks on the surface of the Moon, or any other multi platform collaborative system. We will use the Carnegie Mellon University (CMU) developed Personal Exploration Rovers (PERs) to demonstrate this technology in a terrestrial environment. The adaptation of the software from the aquatic environment to the terrestrial environment began in FY04 but much work still needs to be completed before a demonstration is possible, which includes:

- Complete adaptation software for remote control of PERS, simple goal definition, and display of the PERS positions on a navigational chart.
- Complete enhanced goal definition and perform navigational path planning for the PERs based upon the capabilities/limitations of the PERs and some knowledge of the environment
- Demonstrate of region and feature mapping based upon the high-level goal definition.

We envision using a team from the NASA Robotic Internship Program to augment our civil servant personnel to allow for a more robust demonstration to be developed. Software efforts that the team could potentially work on include: development of a robot positioning/locator system, development of an inter-robot communication systems, or adaptation of the software to a new robotic device. The specifics of the assignments will be further defined once the skills of the interns is assessed.

Team Lead Position Description:

The student team lead would work very closely with the civil servant project lead to define how the work would be distributed among the interns. A team lead with a background in computer engineering would be the most appropriate for this task. Knowledge of both software development and hardware operation would be very beneficial. Experience with the Java programming language is desired as well as an interest in advanced software concepts such as artificial intelligence, planning, and collaborative systems.

Student Intern Position Description:

The interns would work very closely with the civil servant project lead and their coach to define the requirements and design for their assigned task. The interns would then develop the necessary software to implement their design. Tasks would involve developing software modules for interacting with robots. Interns with a background in computer engineering would be the most appropriate for this task. Knowledge of both software development and hardware operation would be very beneficial. Experience with the Java programming language is desired as well as an interest in advanced software concepts such as artificial intelligence, planning, and collaborative systems.

Project Title: Development of Advanced Human-Robot Interfaces for CosmoBot, An Interactive Robot for Children. (HRIC)

PI: Dr. Corinna Lathan, CEO Anthrotronix, Inc.

AnthroTronix Research and Development Background:
AnthroTronix core technology is in the area of advanced interface technology for wearable computers and robotic control systems. AnthroTronix is a leader in development of "gestural" (movement-based) interfaces that combine wearable sensors with voice-activation to control electronic devices via gestures or body movements. AnthroTronix is developing rehabilitation tools to motivate and integrate therapy, learning, and play. These technologies are developed in conjunction with therapists, educators, parents, and children. AnthroTronix has developed CosmoBot™: a robotic toolkit designed for clinical rehabilitation and special education. CosmoBot™ is controlled by body movements, voice activation, or Mission Control, an interactive control station. CosmoBot™ is being tested in clinical and educational settings throughout the development process.

After commercialization, the CosmoBot™ system will consist of CosmoBot™, Mission Control™, and CosmoWeb™. Each component will be able to be used separately or in any combination. Each component in the system will be compatible with off the shelf software, switches, and sensors. The system will be available to educators, schools, rehabilitation facilities, clinicians, and the general public. Partnerships with existing software and hardware companies, and product developers will enhance and strengthen the capabilities of the CosmoBot™ system. We believe that children with disabilities should participate in inclusive education environments and that assistive technology is inclusive technology. For example, Mission Control™ can be used as an interface device to promote sounds and speech for young children without disabilities.

Brief Project Description:
As Principal Investigator of the CosmoBot™ project, Dr. Corinna Lathan will oversee the internship. The NASA internship project will be to primarily focus on robot control input, and secondarily, systems integration of CosmoBot™ and its components. Specifically, robot control input modes include:

- wearable wireless sensors
- speech activation, and
- image based recognition.

Students will focus on the design and development of each mode. Currently, AnthroTronix has a suite of tethered wearable sensors, some voice recognition capacity, and collected data on image based recognition. *The focus of this project is to use the existing foundation, expand on current capabilities, and incorporate the robot controls into the existing CosmoBot™ system.* **The deliverables of this project are working prototypes of each input mode above. The secondary objective is to incorporate the components into the existing robotic system.**

Students will also have the opportunity to recommend changes to the design of the next generation CosmoBot™, planned for late 2005. In addition, students will also be exposed to and asked for input on a variety of AnthroTronix technology related to military robot controllers.

Student Team Lead Position Description:
The most desirable student team lead for this project will have the following technical skills:

- Knowledge of and experience in electrical engineering, knowledge of and experience in software engineering, experience with CAD design, and programming in Windows and Linux.

The most desirable student team lead for this project will have the following general skills:

- This person will be organized, responsible, adept at multi-tasking, and team oriented.

Student Intern Position Description:

The NASA internship project will be to primarily focus on robot control input, and secondarily, systems integration of CosmoBot™ and its components. Specifically, robot control input modes include:

- wearable wireless sensors
- speech activation, and
- image based recognition.

Students will focus on the design and development of each mode, specifically image based recognition. Currently, AnthroTronix has a suite of tethered wearable sensors, some voice recognition capacity, and collected data on image based recognition. *The focus of this project is to use our existing work, expand on our current capabilities, and incorporate the robot controls into the existing CosmoBot™ system.*

Students should have the following skills:

- Computer Science and/.or Electrical Engineering.
- Knowledge of and experience in electrical engineering, knowledge of and experience in software engineering, and programming in Windows and Linux OS.
- Organized, responsible, adept at multi-tasking, and team oriented.
- Ability to work with senior engineers on research, design, test, evaluation, and implementation of technology solutions.
- JAVA, C, C++, Flash and JavaScript desirable but not necessary.

Project Title: Development of Robotic Rover Prototypes for Surface Exploration Tasks (RRPA)

PI: David Akin, UMCP

The University of Maryland Space Systems Laboratory is pleased to submit this proposal to participate in the NASA Robotics Internship Program during the Summer of 2005. We propose to leverage our ongoing NASA robotics research activities to support the educational experience of the summer interns and their student mentor.

Project Description

One of the critical questions affecting the feasibility of future human exploration is the productivity of human/robotic teams. The University of Maryland Space Systems Laboratory has studied this issue extensively in the arena of orbital (microgravity) operations. The next great challenge is to continue and expand this research to planetary surface applications, particularly in the use of robotics to augment and assist astronauts performing geological exploration and search for evidence of extraterrestrial life forms.

We propose that the focus of the 2005 Robotics Internship project at the University of Maryland will be the design and development of a robotic rover to assist spacesuited astronauts performing surface exploration tasks. Since a full-scale rover would be far beyond the scope of this effort, the specific focus would be the design, construction, and testing of a scaled prototype rover, which past SSL experience has shown can be done economically and expeditiously.

Current baseline designs for the astronaut support robot would be a three-body segmented rover, using differential wheel motion and inter-body articulation for steering. Adopting a 1/6 scale factor will result in a prototype rover approximately 18 inches long, which can be quickly implemented using off-the-shelf components such as model airplane servos. The specific research application of the rover will focus on quantifying the control capabilities of the segmented body steering approach, including hazard avoidance and ability to clear obstacles. This research provides an additional opportunity for interaction with NASA Goddard, as rover tests could take place on the MERS (Multipurpose Exoterrain for Robotic Studies) test site at NASA Goddard.

Student Mentor (Team Lead) Job Description

Upper-level undergraduate or graduate student wanted to serve as mentor for team of three freshman-sophomore level undergrads in the NASA Robotics Internship program. Applicants should have significant prior experience in robotics, including design, fabrication, programming, and test operations. Applicants also need interest and capabilities in team building, including both peer-level interactions and serving as a mentor to more inexperienced students. The internship activities will take place over a 10-week period in the summer of 2005.

"VIRTUAL FEEL" ROBOTIC SERVICING

PRINCIPAL INVESTIGATOR: JOHN M. VRANISH, CODE 544
CO-INVESTIGATOR: JULIA LOFTIS, CODE 588
CO-INVESTIGATOR: RUD MOE, HST SERVICING MANAGER

I. BACKGROUND

Robotic assembly/disassembly is dangerous, difficult and prone to jamming and binding between the mating members. Current practice uses cameras, large mechanical guides and mechanical compliance to relieve misalignment forces and force/torque sensing for final assembly and seating. The system is dangerous, large, heavy and out-of-date (early 1990's). Non-contact, compact, electric field sensing is needed to provide pre-contact terminal guidance, to eliminate the misalignments and their derivative forces and to reduce size and weight by greatly reducing mechanical guides and compliance. Accordingly, GSFC engineers developed "Capaciflector" (capacitive reflector) technology over a multi-year effort. Successful, it used an array of sensors with multiple input/output wires to provide precision assembly/disassembly capabilities for robot tools. "Virtual Feel" uses only two (2) Capaciflector sensors and leads, all built into the tool structure. With capable software algorithms (local search, dither, alignment and insertion features), "Virtual Feel" enables precision, non-contact, capture, insertion and tool/fastener seating. The process is analogous to haptic feel that humans use when fitting objects together, except it is non-contact, with no jamming or binding forces, and improves, rather than degrades, control precision and safety. This project is directly applicable to the Hubble Robotic Servicing mission and, beyond that, future robotic servicing and construction missions; in earth orbit; on the Moon and on Mars.

II. OBJECTIVES

Develop tools and techniques for "Virtual Feel" robotic precision servicing in space. Specifically:

- Acquire and assemble desk-top computer controlled robot work station.
- Develop representative tool/fastener/structure mockup hardware.
- Breadboard "Capaciflector" electronic circuits.
- Master and demonstrate robot control skills.
- Develop "Virtual Feel" algorithms.
- Demonstrate and prove out "Virtual Feel" concept.
- Present to Hubble Robotic Servicing team to:
  a. Prove out "Virtual Feel" concept and capabilities.
  b. Position Intern team members to make further contributions to the NASA Hubble Robotic servicing mission.

III. DELIVERABLES

- Tool/Fastener/Structure Mockups.
- "Capaciflector" electronic circuits.
- "Virtual Feel" algorithms.
- "Virtual Feel" precision assembly demonstration and video record of same.
- Reports (mid term and final).
- Real Tool/Fastener designs.

IV. REQUIRED INTERN SKILL SETS

- Electrical Engineering:
  1). Electrical circuits. 2). Sensors.
- Controls Engineering
- Software/Modeling/Computer Scientist:
- Mechanical Engineering:
  1). Tool/Fastener/Structure Mockups. 2). Follow up Real Tool Designs.
- Robotics

V. REQUIRED TEAM LEADER SKILLS

- Establish rewarding, meaningful and visible individual role for each team member.
- Provide day-to-day project management and leadership.
- Provide communication and consultation between project and NASA management.
- Organize and coordinate demonstrations and presentations.

Computer Vision for the ANTS TetWalker (CVAT)

Jacqueline Le Moigne, Michael L. Rilee and John E. Dorband
NASA Goddard Space Flight Center

1. Project Description

With the new NASA Vision for Space Exploration, robotic missions to the Moon could begin as soon as 2008 and will prepare for future collaborative human/robotic missions as well as for future Mars exploration. In this work, we propose to develop computer vision capabilities that will be essential for performing efficient and fast robotic planetary exploration. Tasks such as obstacle avoidance, object detection and recognition, will not be feasible if sophisticated, although simple and fast, vision capabilities are not available on the exploration robots.

Previous computer vision work for autonomous ground vehicles has been performed in the area of 3-dimensional (3-D) scene representation, either utilizing structured light or stereo vision principles. Stereo vision integrates information from 2 or more optical sensors whose respective positions are known, to infer 3-D information about the scene [Mai96]. Structured light utilizes the same principle where one of the camera is replaced by a light (or laser) projection of a pattern which is easier to find in the optical data and whose deformation can be easily and rapidly analyzed to compute the 3-D representation of the robot environment [Lem88]. We propose to review this previous work and investigate its application to the tetrahedron walkers (TetWalkers [TetW04]) developed at NASA Goddard in the framework of the ANTS (Autonomous NanoTechnology Swarm) Mission Architecture. The 3-D information gathered by a 3-D vision system will provide important feedback to TetWalker operators in near-term experiments (e.g. in Iceland or Antarctica). For more advanced missions, the 3-D data will be used by an adaptive synthetic neural system with reflexive and deliberative control that is currently being developed in the framework of a Hubble Space Telescope Recovery Vehicle, simulated in a virtual environment running on a cluster supercomputer.

In the course of this project, a 3-D vision system will be developed, implemented on a prototype TetWalker and demonstrated in the MERS (Multipurpose Exoterrain for Robotic Studies) environment currently constructed at NASA Goddard Space Flight Center.

2. Team Lead Position Description

The work performed by the students team led by the student team lead will involve:

- a brief review of the relevant literature,
- a team analysis of the characteristics of previously developed systems,
- the selection of a 3-D vision system, guided by the PI and co-Is of this proposal,
- the implementation of the corresponding necessary software,
- the development of a prototype vision system on a prototype TetWalker.

In general, the field of study and skills required for the student team lead should include good mathematical background as well as good programming and optical engineering or image processing skills. The following skills are especially desirable:

- Preferred Field of Study: Electrical Engineering or Computer Science
- Required Knowledge
    - C or C++ Programming
    - Geometry and elementary optics

            - Elementary image processing and neural computing
    - Robotics experience a plus (Botball, First, etc …)
    - Responsibilities:
        - Organization and distribution of team work for:
            - Literature review and analysis
            - Modular software development
        - Organization and preparation of system integration for demonstration purposes
        - Writing weekly progress reports and final work report

3. Intern Position Description:

The description is based on a team of 4 students: 3 interns and one coach. The field of study and skills required for the student team should include good mathematical background as well as good programming and optical engineering or image processing skills, as follows:

- **Interns 1 and 2:**
    - Preferred Field of Study: Computer Science
    - Required Knowledge:
        - C or C++ Programming
        - Geometry and elementary optics
    - Robotics experience a plus (Botball, First, etc …)
    - Responsibilities:
        - Team review and analysis of relevant literature
        - Implementation of necessary software (some initial software might be available)
- **Intern 3:**
    - Preferred Field of Study: Electrical Engineering
    - Required Knowledge: Wireless communications, cameras and laser operations
    - Robotics experience a plus (Botball, First, etc …)
    - Responsibilities:
        - Team review and analysis of relevant literature
        - Integration of necessary hardware for demonstration purposes with software developed by the other interns

If interested, students may want to start studying the following references, which describe the basis of their summer work.

[Mai96] M. Maimone S. Shafer, "A Taxonomy for Stereo Computer Vision Experiments," *ECCV Workshop on Performance Characteristics of Vision Algorithms*, April 1996, pp. 59-79.

[Lem88] J. Le Moigne, A.M. Waxman, "Structured Light Patterns for Robot Mobility," *IEEE Journal of Robotics and Automation*, Vol. RA-4, No. 5, 1988.

[TetW04] http://ants.gsfc.nasa.gov/features/4tet_lan.mov

Project Title: Modelling of Tetrahedra-based Robotic Structures (MTRS)
TET Project PI: Dr. Steven A. Curtis (695)/Dr Walt Truszkowski (588)
Internship Program Lead: Dr. Michael Desch (695)

Project Description: [Website: http://ants.gsfc.nasa.gov/tetcontrol.html]
We are building a family of increasingly complex reconfigurable tetrahedral-based robots to support Lunar and Mars exploration. We will soon complete a prototype electromechanical model of a single-tetrahedron (1-TET) walker. This highly-integrated 3-dimensional mesh of actuators and structural elements is composed of nodes that are addressable. The full functionality of such a system requires fully autonomous operations.

Currently, the tetrahedron, is being modeled as a communicating and cooperating/collaborating 4-agent system with an agent associated with each node of the TET. (An agent, in this context, is an intelligent autonomous process capable of deliberative and reactive behaviors as well as social and introspective behaviors.) Three college students and three high school interns contributed significantly to the electro-mechanical design of the 1-TET in the summer of 2004. Their work included mechanical parts selection, CAD analysis, control circuit design and analysis, static scale model fabrication, and web control interface design. The FY05 plan is to design and develop the 4-TET with a payload as the central node, and a 12-TET that could traverse rugged terrain. We also plan to build multiple 1-TET walkers to test schemes for multi-robot (TET-to-TET) collaboration. We anticipate student involvements in all aspects of the design and fabrication of the robotics mechanical structures, and the development of the control scheme and associated electronics and software. An additional problem to be solved is to scale the single TET model up to one capable of supporting autonomous operation for a 12-tet rover (a structure realized by the integration of 12 Tets in a polyhedral structure). The overall objective is to achieve autonomous robotic motion of this 12-tet-based structure. In particular, students can gain valuable hands-on experience by first building an exact duplicate of the current 1-TET, then derive enhanced designs for components, actuators, and control strategies for subsequent TETs.

Internship Program Deliverables: Demonstration of three reconfigurable 1-TET robotic walkers and their collaboration.

Job Description for Student Team Lead:
- An interest in Artificial Intelligence with a focus on agent and multi-agent systems
- Advanced undergraduate student in aerospace, electrical, or mechanical engineering.
- Experience in robotics.
- Course work in CAD analysis, circuit design.
- Computer programming skill in C, Java, html
- Demonstrated creativity in past projects.